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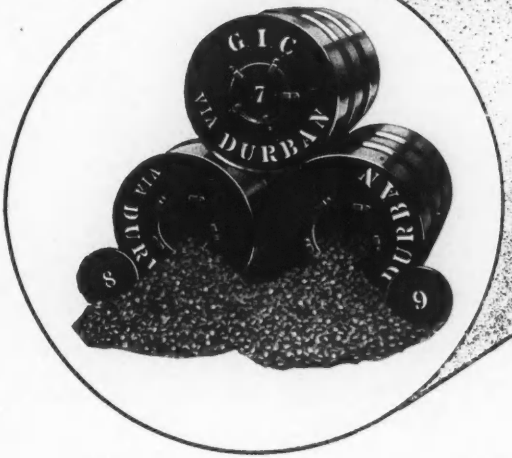

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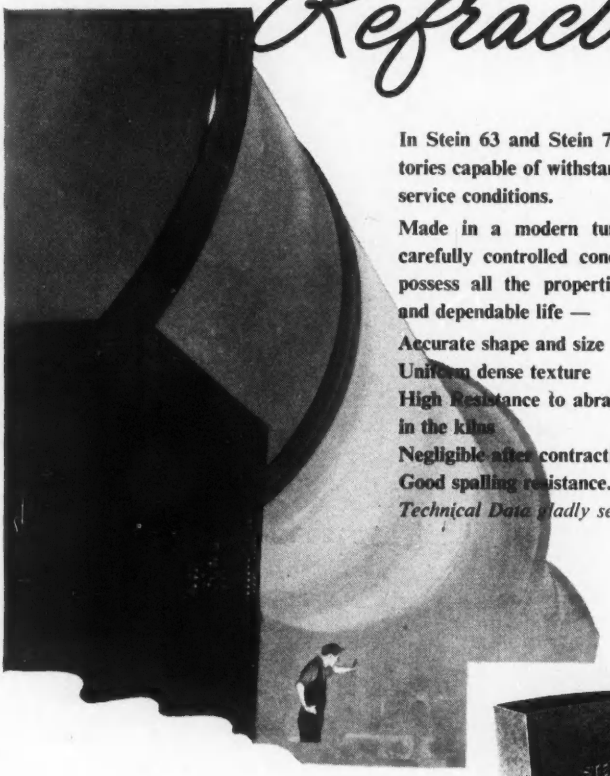

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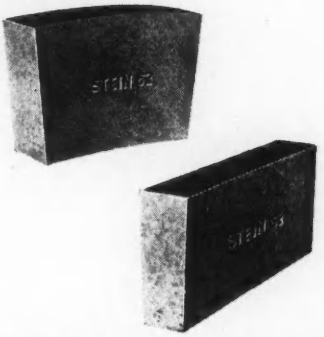

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VOLUME XXIV. NUMBER 6. NOVEMBER, 1951

The Burning, Hydration, and Soundness of Lime.

IN a paper on "Developments in Research on the Burning and Hydration of Lime and on its Use in Building" presented to the Building Research Congress held in London in September, Mr. N. Stutterheim, Mr. T. L. Webb, and Mr. B. Uranovsky of the South African National Building Research Institute reviewed some of the literature of the subject and described experience and research in South Africa. The following is abstracted from the paper, which deals with the basic operations of calcination and hydration, soundness, and physical properties.

Experimental Aspects of Calcination.

The shrinkage of single calcite crystals is found[1] to be 10 per cent. when calcined at 900 deg. C., and increases gradually to 22 per cent. at 1400 deg. C., but does not increase between 1400 deg. C. and 1600 deg. C. Similar results were found for loosely packed calcite powder and compressed pellets. For pure quicklimes the specific gravities were lower than the theoretical values, from which it was deduced that micropores, closed to fluids, are probably present.

One of the investigators[2] considers that the burning characteristics of limestone are largely affected by original porosity and porosity developed during heating, high porosity facilitating calcination, and on theoretical grounds considers it probable that the reaction $CaCO_3 \rightarrow CaO + CO_2$ is dependent on temperature, but not on CO_2-pressure, the reverse reaction, however, depending on temperature and CO_2-pressure. Another[3] found that quicklime from calcite burnt in a laboratory rotary kiln at 950 deg. C. gave the same reactivity towards water whether burnt for a short or a long time, but when calcined at 1300 deg. C. the reactivity was much higher for the longer period in the kiln. High-porosity limes had large surface areas and high reactivity; porosity was largely determined by the rate of heating before and during dissociation, high rates yielding low porosities. For each temperature there was an optimum retention time to produce maximum activity. Surface areas of quicklimes derived from relatively pure calcite ranged

from 2 sq. m. to 17 sq. m. per gramme. Limestone of 98 per cent. purity[4] gave quicklimes having surface areas of only 0·5 sq. m. to 2 sq. m. per gramme ; the porosities of these quicklimes were much higher than those derived from the calcite. Others[5] found that, for a given calcination time, surface areas of quicklimes are lower the higher the temperature. Calcined limestone gave surface areas ranging from 0·2 to 2 sq. m. per gramme ; during burning, the surface areas of quicklimes decreased rapidly for about six hours after complete dissociation.

The mechanism of the thermal decomposition of dolomite does not appear to have been established. Preliminary dissociation into $MgCO_3$ and $CaCO_3$ is discounted[6] on the basis of thermographic analyses. It has been stated [6, 7] that the rate of CO_2 evolution from dolomite is much slower than from magnesite, and attention is drawn to the marked dependence of the rate on the CO_2-pressure.

It has been deduced[8] that the thermal decomposition of dolomite takes place in two steps, namely $CaMg(CO_3)_2 \rightarrow CaCO_3 + MgO + CO_2$ and $CaCO_3 \rightarrow CaO + CO_3$. Similar views are held[9] as a result of thermal analyses on well crystallised samples of almost pure dolomite. It is also considered[10] that the mechanism involves three steps, namely, $CaMg(CO_3)_2 \rightarrow CaO + MgO + 2CO_2$ $CaO + CO_2 \rightarrow CaCO_3$, and $CaCO \rightarrow CaO + CO_2$. The recarbonation of the CaO takes place almost instantaneously. Investigators[11] using isotope C^{13} carbon dioxide in the presence of dolomite during thermal decomposition are attempting to elucidate the reaction mechanism by tracing whether combination of labelled CO_2 with CaO occurs during the assumed transient existence of CaO.

For magnesite it is found[12] that the dissociation rate is determined by CO_2 diffusion through layers of primary oxide particles. It has been observed[13] that the MgO as first formed from magnesite is very finely divided (0·01 to 0·07 micron). With increase in temperature the primary crystals grow to 0·08 to 0·15 micron at 800 deg. C. The pores also increase in size until at about 900 deg. C. the first signs of sintering and shrinkage occur. Sintering takes place more readily if impurities are present. Besides particles of several microns in size, small and apparently uniform particles of about 100-200 Å. occur and may influence the behaviour of the material because of their high surface area. Using powdered dolomite calcined at various temperatures, it is found[14] that hydrate surface areas are similar to those of the calcinates formed below 1050 deg. C. For calcinates burnt at higher temperatures, a considerable increase in hydrate surface area was found.

The effects of various solids and gases on the decomposition of limestones and dolomites have apparently not been studied systematically. One investigator[15] concludes that water vapour catalyses the decomposition. This study justifies more attention because of its practical importance.

Practical Aspects of Calcination.

The principal developments in industrial lime production concern kiln design, methods of firing, use of graded charges, and improvement in temperature control and fuel efficiency. For mixed-feed kilns improved charging and draught control, more frequent drawing, and the use of anthracitic coal or coke have led to better

control of burning and a more uniform product. For shaft kilns the trend is away from mixed feeding towards forms of gas firing. Arrangements for combustion of gases in the interstices of the charge and for gas recirculation are considered more efficient, the gases being introduced near the axis of the kiln to obtain more uniform temperatures across the section and reduce channelling along the walls. It is an advantage from the point of view of heat exchange and rate of calcination to use small stone. A recent introduction is lime kilns operating on the fluidised-bed principle, high thermal efficiency and close temperature control being obtainable, but grinding and grading of the material are necessary and it must be free from dust.

Experimental Aspects of Hydration.

Although burning conditions have a pronounced effect on the hydration characteristics, little fundamental work has been published recently on the hydration of high-calcium limes. Investigators[1] studying the hydration of very pure CaO at 60 deg. C. in CO_2 free air of 90 per cent. relative humidity obtained the

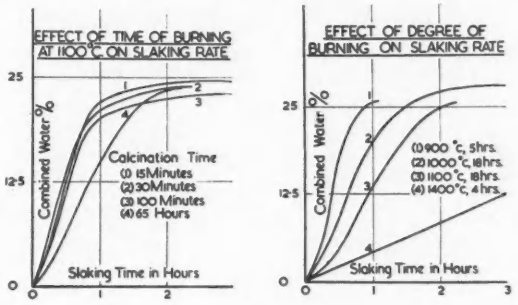

Fig. 1.

results given in *Fig.* 1. They conclude that hydration is a phase boundary reaction, in which water molecules are absorbed and then transported by diffusion to the most active places, such as crystal corners and edges, before reacting. Mechanical disintegration takes place at the reaction zones, thus making further edges available for hydration. The rate of hydration increased with increase in surface area and reduction in particle size, though an activity factor also plays a part. They consider that hydration is much more complex when liquid water is present.

Much work has recently been done on the hydration of magnesia derived from magnesian limestone, dolomite, or magnesite. A study[16] of the system MgO-H_2O showed that hydration consists of rapid initial water absorption followed by slow hydration. It has also been found[17] that the rate of hydration of MgO derived from a magnesite is four to six times slower than that of pure MgO; increase in calcination temperature caused a logarithmic reduction in the rate of hydration which was proportional to oxide surface-area. It was observed that the rate of hydration of MgO fell rapidly when its free moisture content was

less than about 1 per cent. It is also found[18] that the presence of a little CaO increased the rate of hydration of MgO, whereas the presence of Al_2O_3, SiO_2 and Fe_2O_3 in the burnt material inhibited hydration, which is assumed to be due to the formation of a protective coating during burning.

The authors carried out an investigation of the hydration of calcinates derived from two South African dolomites and one magnesite burnt in a laboratory furnace at temperatures of 600 deg. to 1400 deg. C. for periods of 1 to 48 hours. The result for 30 hours of calcination with respect to MgO, hydrated with five times the theoretical amount of water, is shown in *Fig.* 2. In the presence of liquid water, the CaO hydrated rapidly and completely for all temperatures and times studied. Comparison of the results for magnesia in dolomitic lime and in calcined magnesite showed remarkable differences particularly in the range of 600 deg. to 1100 deg. C. For calcined magnesite the degree of hydration decreased as the calcination temperature increased, until for 1400 C. deg. it was negligible. For the dolomitic magnesia the degree of hydration was greatest for the 900 deg. C.

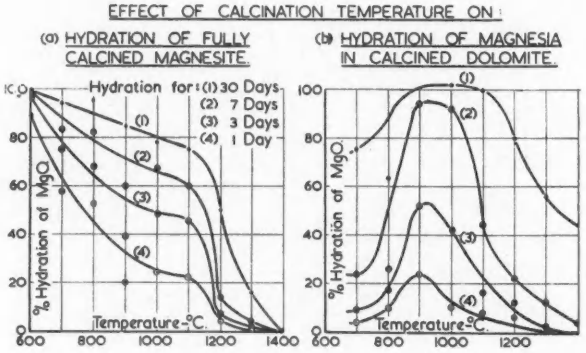

Fig. 2.

material. In saturated steam the rate of hydration increased rapidly with increase of steam pressure, but decreased with increase of calcining temperature, so that the magnesia in a dolomitic lime calcined at 1400 deg. C. required more than two hours for complete hydration in saturated steam at 300 lb. per square inch. In superheated steam at 140 deg. and 185 deg. C. and atmospheric pressure CaO hydrated readily, but no hydration of magnesia occurred in calcined dolomite or magnesite even after 24 hours. The mechanisms of the hydration reactions for the two oxides appear to be basically different. It is likely that liquid water has to be present if MgO is to hydrate.

Slaking-temperature surveys in South African lime plants show that shortly after adding water the temperature rises to over 100 deg. C. and sometimes to nearly 300 deg. C., the free moisture content of the lime then being almost negligible. Since magnesia does not appear to hydrate in dry steam, magnesian

and dolomitic limes slaked in heaps or mechanical hydrators contain little $Mg(OH)_2$.

Unsoundness.

Unsoundness of lime is an urgent problem in South Africa. The calculated volume increase upon hydration of CaO and MgO is about 100 per cent. and 120 per cent. of the oxide volume respectively. Commercial dolomitic limes produced in mixed-feed kilns and hydrated mechanically or on slaking floors have less than 25 per cent. of their magnesia hydrated. Yet unsoundness in practice is infrequent, demonstrating that unhydrated magnesia could probably exist without causing expansion. Chemical and differential thermal analyses of mortars of various ages corroborated this view, and it is concluded that, if hydration of magnesia be responsible for failure, the magnesia must be in an unusual state. One investigator [19] concludes that there does not seem to be a relation between the behaviour of unhydrated magnesia in autoclaved specimens and its behaviour under various laboratory ageing conditions. Using bond strength as a criterion, he found that magnesia hydrates in experimental mortar

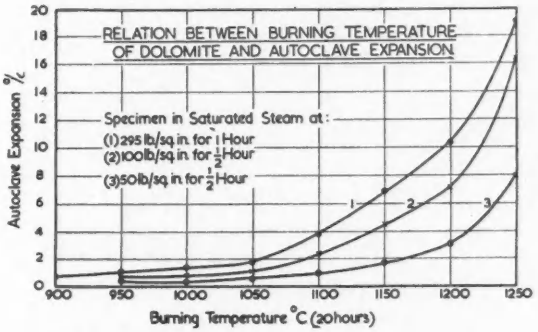

Fig. 3.—Results of Tests by W. L. Leinberger.

joints without harmful effects. Others [20] found correlation between the unhydrated oxide content of dolomitic limes and autoclave expansion, and propose a limit of 1 per cent. autoclave expansion as the criterion for lime soundness. In the autoclave test South African magnesian and dolomitic limes generally gave expansions of 10 per cent. to 25 per cent. Since it is known that such limes do not usually cause unsoundness, this test does not differentiate between what are in practice sound and unsound products, though it may give an indication of potential capacity for unsoundness. Other laboratory studies have established the relationship between calcination temperature of dolomitic lime and its autoclave expansion (*Fig.* 3). Below 1050 deg. C. expansions were small, but for higher calcination temperatures expansions increased rapidly. Differential thermal analyses taken just before and after autoclave tests at 295 lb. per square inch indicated that negligible hydration of magnesia had taken place before autoclaving, but that virtually full hydration occurred during the pressure treat-

ment (*Fig.* 4). For a particular lime, expansion decreased with decrease in autoclave pressure (*Fig.* 3). Specimens used for the autoclave tests, if treated with saturated steam at atmospheric pressure, were found to give much smaller expansions.

It has also been found[14] that a sample of unbonded powdered calcined magnesite loaded to 1 lb. per square inch had a linear expansion of 35 per cent. on autoclaving but only 12 per cent. when loaded to 7 lb. per square inch. These loads are similar to those exerted on mortar near the top and bottom respectively of a 10-ft. wall. The greater incidence of expansive cracking of mortar joints in the upper courses of walls may be due to a similar phenomenon, of which there are several possible explanations. There is evidence that low-temperature calcinates have a high percentage of fine pores and the hydration products could possibly expand into such pores without significantly increasing the bulk volume. The authors have, however, failed to find correlation between pore content and auto-

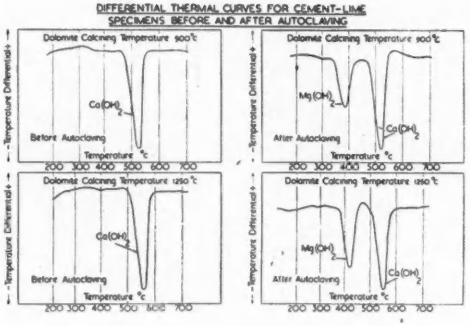

Fig. 4.

clave expansion. There is also evidence that materials burnt at low temperatures consist of discrete particles while at higher temperatures particles tend to sinter, and for materials burnt at low temperature expansion might therefore have less effect on the volume.

Although there may be no adequate correlation between autoclave expansion or MgO-content and unsoundness in practice, pressure-hydrated limes have been found to be sound.

Degree of Hydration.

It is of importance to ascertain the degree of hydration of a lime. If magnesia is present it is difficult to apportion the water of hydration. One conclusion[21] is that water in a hydrated magnesian or dolomitic lime should be preferentially allotted to the CaO, and that water in excess of the stoichiometric requirements of the CaO should be allocated to the MgO. This conclusion is valuable but should be applied with discretion because, although the compound composition of a dolomitic lime may be correctly calculated from this assumption, in the

case of a mixture of two or more limes the method could lead to error if CaO and $Mg(OH)_2$ co-existed in the mixture. For limes containing silicates and aluminates, the compound-composition calculations may be subject to additional sources of error.

The authors are investigating the possibility of determining lime composition quantitatively by differential thermal analyses. Promising results have been obtained, but standardisation is essential. Variation in the distribution of particles of different sizes is a source of error. An interesting observation is that, for an intimate stoichiometric mixture of dolomite and $Ca(OH)_2$, the endothermic peak due to the decomposition of the $MgCO_3$ in the dolomite virtually disappears, which is considered to be due to the instantaneous exothermic combination of the evolved CO_2 with CaO derived from the $Ca(OH)_2$, the two thermal effects practically cancelling. Results obtained with proportions other than stoichiometric seem to confirm this, and related effects are observed with mixtures of $Mg(OH)_2$ and CaO, $CaCO_3$, and SyO.

Plasticity of Lime.

Research on the relation between plasticity of lime and other factors has elucidated some important relationships. It is considered[21] that plasticity increases with increase of hydrate surface area. It has also been found[22] that there is correlation between plasticity of lime and particle shape and that increase in slaking temperature tends to reduce plasticity, dolomitic limes tending to be more plastic than high-calcium limes due possibly to less overheating during slaking. An optimum slaking temperature for maximum plasticity of dolomitic limes has been established.[23] The authors have found that the plasticity of dolomitic limes decreases as the calcining temperature increases, autoclaving not appearing to have a marked effect on plasticity. Ball milling increases plasticity considerably, particularly for hydrates derived from low-temperature calcinates. Soaking for 24 hours increases plasticity whether the lime has been pressure-hydrated or not. It is concluded that the lowest economic burning temperature compatible with complete decarbonation yields a product which hydrates easily to give a more plastic hydrate. Plasticity also seems to be related to the size and nature of the particles.

Rate of Burning.

In the discussion following the presentation of the paper, Professor Voss of the Massachusetts Institute of Technology, stated that tests showed that the rate of raising the temperature of the kiln was more important than the maximum temperature reached or the time at maximum temperature. He explained that slow heating due to burning wood produced a good lime, but quicker burning with coal or oil produced poorer limes, the completion of the hydration of which occurred when the lime was in use in a building. The hydration of slowly burnt lime occurred in a few seconds, but very much longer was required for quickly burnt limes. He agreed that the autoclave test was not reliable, and stated that the difficulty with plasticity was how to measure this properly.

Mr. Stutterheim in reply gave the results of tests which showed that raising the temperature slowly to 900 deg. C. produced a sound lime, and an unsound lime was produced by raising the temperature quickly to 1400 deg. C., but sound lime was produced by raising the temperature slowly to 900 deg. C. and then to 1400 deg. C.

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Composition of Pozzolana Cements.

IN "Revue des Materiaux" for February, 1951, F. Ferrari describes further studies of pozzolana cements. The addition of pozzolana prevents disintegration of cements containing permeable calcium hydrate, a soluble substance of low cementitious value, resulting from the hydrolysis of tricalcium silicate. The resistance to sulphates of pozzolana cement varies with the content of tricalcium-aluminate, and is indicated by the amount of Al_2O_3 being less than that of Fe_2O_3. Mortars of pozzolana cement harden in air as quickly as do mortars of ordinary Portland cement in water. The greatest durability is obtained by a cement having a low alkali content, and the composition suggested is SiO_2, 25 per cent.; Al_2O_3, 3 per cent.; Fe_2O_3, 5 per cent.; $4CaO.Al_2O_3.Fe_2O_3$, 15 per cent.; CaO, 64 per cent.; and $3CaO.SiO_2$, 43 per cent.

Temporary Cement Works in Spain.

FOR the construction of several concrete dams in Spain the cement required has been made in temporary works at the sites. When large quantities of cement are required daily and if suitable raw materials are obtainable locally, the advantages of this method are that the amount of construction materials to be transported to the site is reduced and a regular supply of cement is more assured for sites to which access is difficult. Also, lorries and containers are not exclusively engaged on transporting cement for the duration of the work, and there is less demand for large quantities of cement from permanent works that may be fully occupied in supplying cement for other purposes. A temporary cement works is costly, and the capital charges must be amortised on the quantity of cement required for the works and in a much shorter time than is usual with a permanent

Fig. 1.

factory. Particulars of the temporary cement works described in the following are taken from an article by D. Choffat in " Cemento-Hormigon " for May, 1951.

A dam on the River Turia in Benageber is a gravity structure containing more than 600,000 cu. yd. of concrete and requiring about 110,000 tons of cement. A temporary cement works was installed by the Compania General de Asfaltos y Portland Asland and, having an annual productive capacity of 20,000 tons, produced sufficient cement to make 106,000 cu. yd. of concrete in 1945, 117,000 cu. yd. in 1946, 131,000 cu. yd. in 1947, 119,000 cu. yd. in 1948, and the remainder in 1949 and 1950. The works, which were adjacent to the concrete mixing plant, were erected on the side of a mountain (*Fig.* 1), the plant for various stages of manufacture being at successively lower levels (*Fig.* 2).

The deposits available on the higher slopes of the mountain enabled two materials to be prepared, one a limestone of high calcium-carbonate content

and the other a mixture of clay and limestone with a much smaller content of calcium carbonate. From the crusher (A), *Fig.* 2, the materials passed to separate bins (T) from which the amounts of each material required to give the correct mixture were extracted and passed through a dryer (R).

From the dryer, the raw material was discharged into a ball-mill (O) in which the first stage of the grinding was done. The coarsely ground material was then fed into a finer grinding mill in which it was ground until the residue on a sieve of 4,900 meshes per square centimetre did not exceed 6 per cent. Up to this stage movement of the raw material was entirely by gravity, but the powdered material was then taken by a screw-conveyor to the first silo (C). From this silo it was extracted by a screw-conveyor and by means of an elevator was carried to a second silo, in the bottom of which was a distributor synchronised with the rotation of the kiln (H) so that the kiln was fed uniformly.

The kiln was 131 ft. long and 8 ft. 3 in. diameter. The cooler (F) was at right-angles to the kiln to suit the level of the ground, and in this position it was not

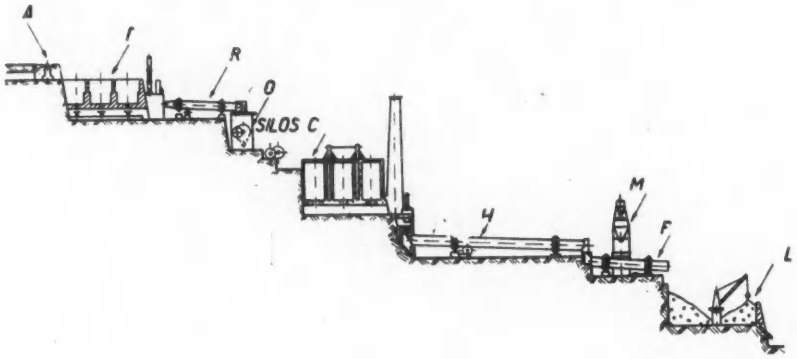

Fig. 2.

necessary to undertake considerable excavation. Upon leaving the cooler the clinker was weighed and put in an open-air store (L) which could hold 5,000 tons. The coal was brought to the site by motor lorry and deposited at the same level as the raw-material dryer so that it fell by gravity to the coal-mill (M) into which was injected a blast of warm air from the cooler. Thus the coal was dried and crushed simultaneously, and transported by the current of air to a cyclone from which it was fed into the kiln. The properties of the crushed coal were 10 per cent. volatile material, 35 per cent. ash, and 5 per cent. residue on a sieve of 4,900 meshes per square centimetre.

From the store (L) the clinker was loaded into wagons, which were drawn up a ramp to a store at the level of (R), and was passed through the dryer (*Fig.* 3). The clinker and gypsum were then passed through the same coarse mill (O) and fine mill as the raw materials and, after being ground, was fed into one of the silos

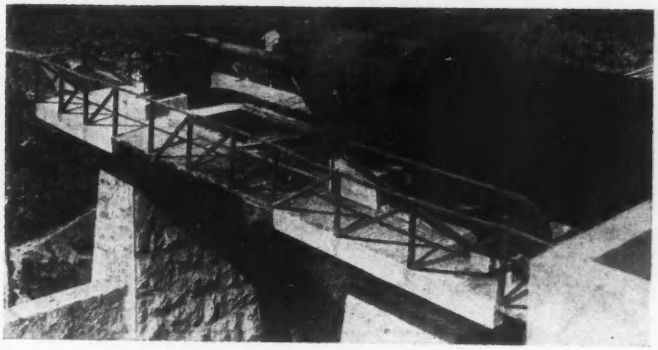

Fig. 3.—Clinker Dryer.

(C) from which it was transported pneumatically through a pipe 820 ft. long to a 800-tons silo at the concrete mixing plant.

The double use of the mills and the grinding of the coal without preliminary drying may appear to be unfavourable to the regular production of cement, but it is said that, although the works were far from perfect, they produced with sufficient regularity during 5½ years cement of the quality required for the dam. The plant was planned to minimise the amount of labour and power required; as a result, the consumption was about 82 kw.-hour per ton of cement.

A temporary cement works for a dam in course of construction near Oliana on the River Segre is planned to produce 70,000 to 80,000 tons in two years. Because the stone near the dam has a high magnesia content, the works are placed about six miles away near a coal mine and not far distant from deposits of suitable limestone.

Bibliographies of Cement.

THE Cement & Concrete Association issues bibliographies dealing with various subjects relating to concrete and containing references to books, articles in technical journals, papers presented to institutions, and other literature in the Association's library. Bibliographies relating to cement issued so far are "The First 100 Years of Patents on Cement and its Manufacture"; "Air-entrained Concrete"; "Expanding Cements"; "Bulk Cement"; and "Pozzolana Cement." Copies can be obtained free from the Association at 52 Grosvenor Gardens, London, S.W.1.

False Setting Due to Dehydrated Gypsum in Portland Cement.

FALSE setting of Portland cement is generally attributed to the hydration of dehydrated gypsum, the identification of which is considered by Mr. J. L. Gilliland in the " Journal of the American Concrete Institute" for June, 1951, from which the following notes are abstracted.

Some investigators[1] conclude that the presence of dehydrated gypsum is due to high temperature during grinding and to the storage of hot cement. Five forms of dehydrated gypsum have been identified,[2] namely, (1) $CaSO_4.\frac{1}{2}H_2O(\alpha)$—

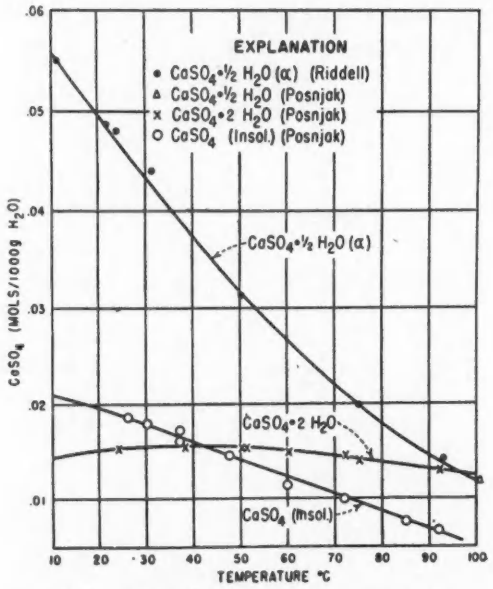

Fig. 1.—Solubilities of Calcium Sulphates.

a hemihydrate of calcium sulphate commonly known as plaster of Paris; (2) $CaSO_4.\frac{1}{2}H_2O(\beta)$—a more unstable form of plaster of Paris; (3) $CaSO_4$(sol. α)—a soluble anhydrite prepared from the α-hemihydrate; (4) $CaSO_4$ (sol. β)—a soluble anhydrite prepared from the β-hemihydrate; and (5) $CaSO_4$ (insol.)—the insoluble anhydrite. Although the principal forms of calcium sulphate can be distinguished from one another by X-ray diffraction patterns and by differential thermal curves, these methods are not suitable for identifying the various forms in Portland cement.

Calcium-sulphate hemihydrate has a metastable solubility considerably higher than the solubility of gypsum or insoluble anhydrite. Therefore it is possible to

identify hemihydrate by solubility tests. Generally, cements showing false setting in the penetration test give, in solubility tests, liquid extracts supersaturated with gypsum.

The solubilities in water of $CaSO_4.2H_2O$, $CaSO_4.\frac{1}{2}H_2O(\alpha)$, and insoluble $CaSO_4$ are shown in *Fig.* 1. The values for $CaSO_4.2H_2O$ and insoluble $CaSO_4$ were reported by Posnjak,[3] and the values for $CaSO_4.\frac{1}{2}H_2O(\alpha)$ by Riddell[4]. The solubility curve for hemihydrate represents a metastable condition. Since this solution is supersaturated with dihydrate, at room temperature gypsum precipitates until the solubility shown by the gypsum curve is reached. The conversion of hemihydrate to dihydrate is not too rapid to prevent the use of solubility

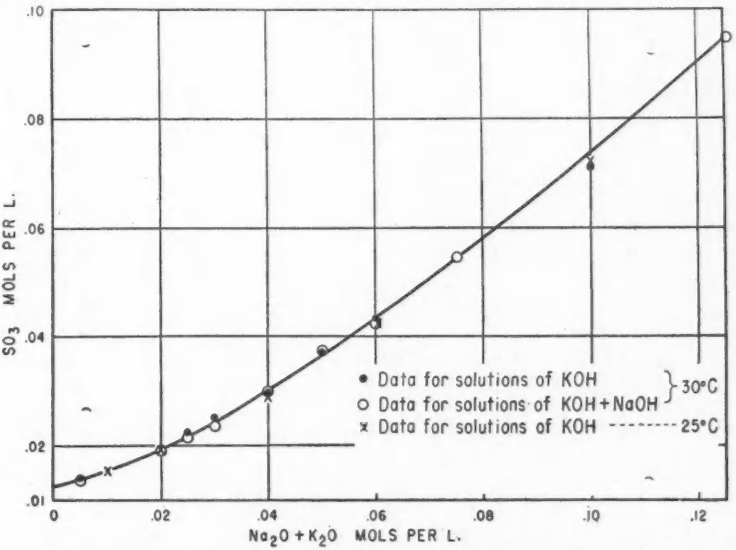

Fig. 2.—Solubility of Gypsum in Saturated Calcium Hydroxide Solutions containing Alkali Hydroxides.

data for identifying hemihydrate in Portland cement if the extraction is made quickly.

Messrs. Hansen and Pressler[5] determined the solubility of gypsum in saturated calcium-hydroxide solutions containing various amounts of sodium and potassium hydroxides. The solubility of gypsum under these conditions is shown in *Fig.* 2, from which it is seen that the solubility of gypsum is a function of the alkali concentration if the solution is saturated with calcium hydroxide. The data were used to establish whether the liquid phases of cement pastes were supersaturated with gypsum, and it was concluded that, where a supersaturated condition was found, it was due either to greater solubility of hemihydrate, or to extreme fineness

of the gypsum resulting from grinding. From X-ray diffraction studies it was found that it is almost impossible to prevent gypsum from dehydrating during fine grinding, and therefore it seems logical to assume that the high solubility of finely-ground gypsum reflects the solubility of the hemihydrate. The acceptance of this assumption permits the identification of hemihydrate on the basis of the composition of the extract. Insoluble anhydrite cannot be identified from the composition of the extract, since its solubility is close to that of gypsum.

The gypsum saturation test, adapted from the work of Messrs. Hansen and Pressler, was applied to a number of cements which had been tested for false setting by the penetration test described by Messrs. Blanks and Gilliland.[1] The cement paste was vigorously agitated for a short period. The solid phase was then quickly filtered out before the more stable dihydrate could crystallise from the extract solution. It is thought that the solubility values reflect the condition of calcium sulphate in the cement rather than equilibrium conditions in the presence of gypsum. Cements passing the penetration test showed only a small amount of SO_3 in excess of the gypsum-saturation curve, and cements which failed to pass the penetration test were supersaturated with gypsum, indicating the presence of significant amounts of hemihydrate.

Heating at low temperatures (about 120 deg. C.) induces false set, but at higher temperatures (about 350 deg. C.) the setting is normal. The gypsum saturation test follows this change, identifying the hemihydrate in cement with false setting.

Aeration also induces false setting of cement. It was once thought[6] that the alkalis became carbonated during aeration and precipitated calcium carbonate immediately the water was added to the cement. Tests described by Mr. Gilliland show, however, that the temperature (about 350 deg. C.) at which normal setting is restored is much lower than the temperature at which alkali carbonates are decomposed, and that the form of the gypsum is altered.

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Composition of Slag for Slag Cement.

IN recent numbers of "Revue des Materiaux," M. L. Blondiau shows that the ratio of CaO to SiO_2 in the slag is as important as the granulation of the slag in producing satisfactory blastfurnace-slag cement. The optimum ratio is 1·45 to 1·54 accompanied by a ratio of SiO_2 to Al_2O_3 of 1·8 to 1·9 and a difference of 70 cal. to 80 cal. per gramme in the heat of hydration between ordinary Portland cement and the slag cement.

A New Cement Works in North Africa.

THE NEW cement works of the Société des Ciments Artificiels d'Oranie, at Oran, North Africa, was recently put into operation. The following notes and accompanying illustration are from " Revue des Materiaux de Construction."

Stone is brought from a quarry (N) by a transporter (P) to the crushing plant, which comprises an Allis-Chalmers primary gyratory crusher which reduces the lumps to about 5 in., a secondary hammer-type crusher, and two vibrating screens. This equipment is in a closed circuit, and produces material about $\frac{5}{8}$-in. down, which is transported by two band-conveyors to the store (A). The store is a reinforced concrete building 590 ft. long and 98 ft. wide and contains, in addition to the crushed stone (B), the coal, and the clinker from the kiln. Two 10-tons overhead cranes are provided for handling the materials. The coal is unloaded by

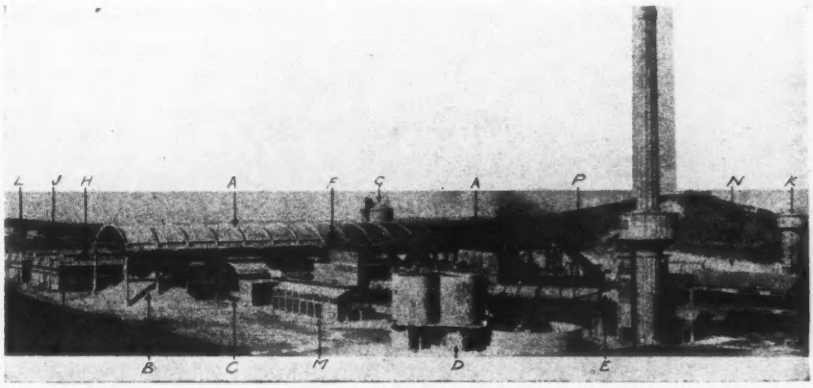

Fig. 1.—New Cement Works at Oran.

the cranes from wagons, in which it arrives in lumps. When required for burning, it is passed through a rotary dryer which discharges into a crusher, from which the pulverised coal is blown through pipes by Fuller air-pumps to the feed-hopper of the kiln.

The raw-material crusher (C) is a three-stage ball-machine fed from a hopper into which the stone is placed by the overhead cranes. Water is added to the finely crushed material which, as a slurry, is pumped by centrifugal pumps to the mixing tanks (D). There are four tanks each of 588 cu. yd. capacity, and in these are mixed in the required proportions calcareous and argillaceous slurries derived from material obtained from different parts of the quarry. From the mixing tanks the slurry passes to two storage tanks each of 1,300 cu. yd. capacity. Centrifugal pumps transport the slurry to the kiln.

The kiln (E), which is fired with pulverised coal, is 351 ft. long, 11 ft. 6 in. diameter, and is carried on six supports. The temperature of the clinker is reduced

to about 60 deg. C. in a Fuller cooler (F) into which the clinker is fed while incandescent. The clinker is carried from the cooler to the store by a chain-conveyor. The air heated in cooling the clinker is returned to the kiln. The clinker is transferred by crane from the store to two ball-type crushers from which the ground clinker is blown through pipes by two pumps, similar to those used for the pulverised coal, to three silos (G). Each silo has a capacity of 2,500 tons, and at the outlet is a four-bag automatic packing machine. Transporters, which carry the bags of cement to railway wagons or motor lorries, can deal with 80 tons per hour.

Auxiliary structures include a workshop (H), stores (J), a laboratory, an electricity substation (M), and a water tower (K) which has a capacity of about 200,000 gallons and is supplied from a well 215 ft. deep. Electricity is supplied at 5,000 volts from the public supply and is used directly by the motors of the crushers, but is transformed to 380 volts for other machines and to 230 volts for variable-speed motors. The annual consumption is 10,000,000 to 12,000,000 kw.-hours of electricity, 30,000 to 35,000 tons of coal, and 33,000,000 gallons of water. The amount of limestone and clay treated in a year is 180,000 tons which produces 120,000 tons of cement. Houses (L) for persons employed at the works have been built.

Construction of the works, which commenced in December 1949, required the excavation of about 60,000 cu. yd. of earth, and in the structures and foundations there are 15,000 tons of cement and 4,000 tons of reinforcement. The labour required was 2,000,000 man-hours. The works were put in operation at the beginning of 1950 and by the end of that year had produced 115,000 tons of cement. The cement produced is highly siliceous and offers great resistance to attack by sea-water.

Cement Works in Belgian Congo.

IT is expected that the new cement factory now under construction at Kimba will be producing early in the year 1953; the capacity will be about 140,000 tons a year. In the meantime there is a serious scarcity of cement in the Belgian Congo as a result of which the duty on imported cement has been removed and railway rates have been reduced.

It was reported recently that a company known as Les Ciments Metallurgiques de Jadotville, with a capital of 40 million francs, has been formed with the object of erecting a new cement factory at Jadotville.

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INDEX TO VOL. XXIV, 1951

PAGE

Africa, A new cement works in North... 111
Air-entrained concrete, Cellular and, by J. P. Levy ... 55
Angola, The cement industry in 69

AUTHORS:

Azbe, Victor J., on A rotary lime kiln 1
Blondiau, L., on Composition of slag for slag cement 110
Bucci, R., on Reactions of the sulphates during the setting of Portland cement 95
Ferrari, F., on Composition of pozzolana cements... 104
Gilliland, J. L., on False setting due to dehydrated gypsum in Portland cement 108
Lerch, W., on Gypsum in Portland cement... ... 13
Levy, J. P., on Cellular and air-entrained concrete... 55
Nurse, R. W., on Specification tests for specific surface of cements 17
Pfrunder, V. R., on The pneumatic method of conveying cement 68
Rebuffat, A., on Kaolin and zeolites... 95
Santarelli, L., on Fuel consumption in cement works 31
Santarelli, L., and A. Guzzini on Pozzolana cement 95
Saul, A. G. A., on Suggested principles of low-pressure steam curing of mortar and concrete... 39
Stutterheim, N., T. L. Webb, and B. Uranovsky on The burning, hydration and soundness of lime ... 97
Tavasci, B., on Porosity of hydrated Portland cement 96
Taylor, H. F. W., and G. E. Bessey on Hydro-thermal reactions in the lime-silica-water system 47

Belgian Congo, Cement machinery for the 12
,, Cement works in 112
Belgium, The cement industry in 52
Bibliographies of cement 107
Blastfurnace-slag Portland cements, Determination of the composition of 61
Britain, The cement industry in 67
Burning, hydration and soundness of lime, by N. Stutterheim, T. L. Webb, and B. Uranovsky ... 97

Cellular and air-entrained concrete, by J. P. Levy ... 55
Cement, Bibliographies of 107
,, Expanding 32, 45
Chatelier, Henry le 7
Clinker-slag cement, A new French 94
Concrete in marine works, Defective mortar and ... 11
Conveying cement, The pneumatic method of, by V. R. Pfrunder 68
Costa Rica, The cement industry in 69
Cuba, New cement kiln for 94
,, The cement industry in 70

PAGE

Curing of mortar and concrete, Suggested principles of low-pressure steam, by A. G. A. Saul 39

Expanding cement 32, 45
False setting of Portland cement 96
Finland, The cement industry in 52
France, A large rotary kiln in 35
French clinker-slag cement, A new 94
Fuel consumption in cement works, by L. Santarelli 31
Fuel, Storing 93
Gypsum in Portland cement, by W. Lerch 13
,, in Portland cement. False setting due to dehydrated, by J. L. Gilliland 108
,, Some views on the action of 33

Heat of hydration of Portland cement, Accuracy of test for 38
Hydration and soundness of lime, The burning, by N. Stutterheim, T. L. Webb and B. Uranovsky ... 97
,, of Portland cement, Accuracy of test for heat of 38
Hydrothermal reactions in the lime-silica-water system, by H. F. W. Taylor, and G. E. Bessey ... 47

Indonesia, The cement industry in 70
Iraq, A new cement works in 6

Japan, The cement industry in 52, 70

Kaolin and zeolites, by A. Rebuffat 95
Kiln, A large rotary 6
,, A rotary lime, by Victor J. Azbe 1
,, in France, A large rotary 35
Kilns in the lime industry, Vertical 21

Lime industry, Vertical kilns in the 21
,, kiln, A rotary, by Victor J. Azbe 1
,, -silica-water system, Hydrothermal reactions in the, by H. F. W. Taylor and G. E. Bessey ... 47
,, The burning, hydration and soundness of, by N. Stutterheim, T. L. Webb and B. Uranovsky ... 97

Malaya, Proposed new cement works in 16
Manufacture, Raw materials in cement 46
Marine works, Defective mortar and concrete in ... 11
Materials in cement manufacture, Raw 46
Mexico, The cement industry in 52
Mortar and concrete in marine works, Defective ... 11
Mozambique, Cement works in 30

Netherlands, Specifications for cement in the ... 53

Pakistan, The cement industry in 70
Pneumatic method of conveying cement, by V. R. Pfrunder 68
Porosity of hydrated Portland cement, by B. Tavasci 96
Portugal, A new cement works in 9

INDEX—*continued from previous page*

	PAGE
Pozzolana cement, by L. Santarelli and A. Guzzini	95
,, cements, Composition of, by F. Ferrari	104
Sacks, The transport of cement in special	44
Safety competition in cement works	8
Setting due to dehydrated gypsum in Portland cement, False, by J. L. Gilliland	108
,, of Portland cement, False	96
,, of Portland cement, Reactions of the sulphates during the, by R. Bucci	95
,, time of Portland cement, Mechanical determination of the	30
Shoreham, New cement works at	71
Silicates in Portland cement	8
Slag cement, A new French clinker-	94
,, for slag cement, Composition of, by L. Blondiau	110
,, Portland cements, Determination of the composition of blastfurnace	61
Soundness of lime, The burning, hydration and, by N. Stutterheim, T. L. Webb and B. Uranovsky	97
Spain, Cement production in	30
,, Temporary cement works in	105
Specific surface of cements, Specification tests for, by R. W. Nurse,	17
Specifications for cement in the Netherlands	53
,, of the world, Portland cement	22, 57
Standard for sulphate-resistant Portland cement, United States	51
Standards for cement, United States	8
Steam curing of mortar and concrete, Suggested principles of low-pressure, by A. G. A. Saul	39
Sulphate attack, A test of the resistance of Portland cement to	65
,, -resistant Portland cement, United States standard for	51
Sulphates during the setting of Portland cement, Reactions of the, by R. Bucci	95
Surface of cements, Specification tests for specific, by R. W. Nurse	17
Switzerland, The cement industry in	52
Temporary cement works in Spain	105
Test for heat of hydration of Portland cement, Accuracy of	38
,, of the resistance of Portland cement to sulphate attack	65
Tests for specific surface of cements, Specification, by R. W. Nurse	17
Transport of cement in special sacks	44
Turkey, The cement industry in	70
United States standard for sulphate-resistant Portland cement	51
,, ,, standards for cement	8
Uruguay, The cement industry in	70
Works at Shoreham, New cement	71
,, in Belgian Congo, Cement	112
,, in North Africa, A new cement	111
,, in Spain, Temporary cement	105
Zeolites and kaolin, by A. Rebuffat	95